PROPULSION DIRECTORATE

Monthly Accomplishment Report
April 2001

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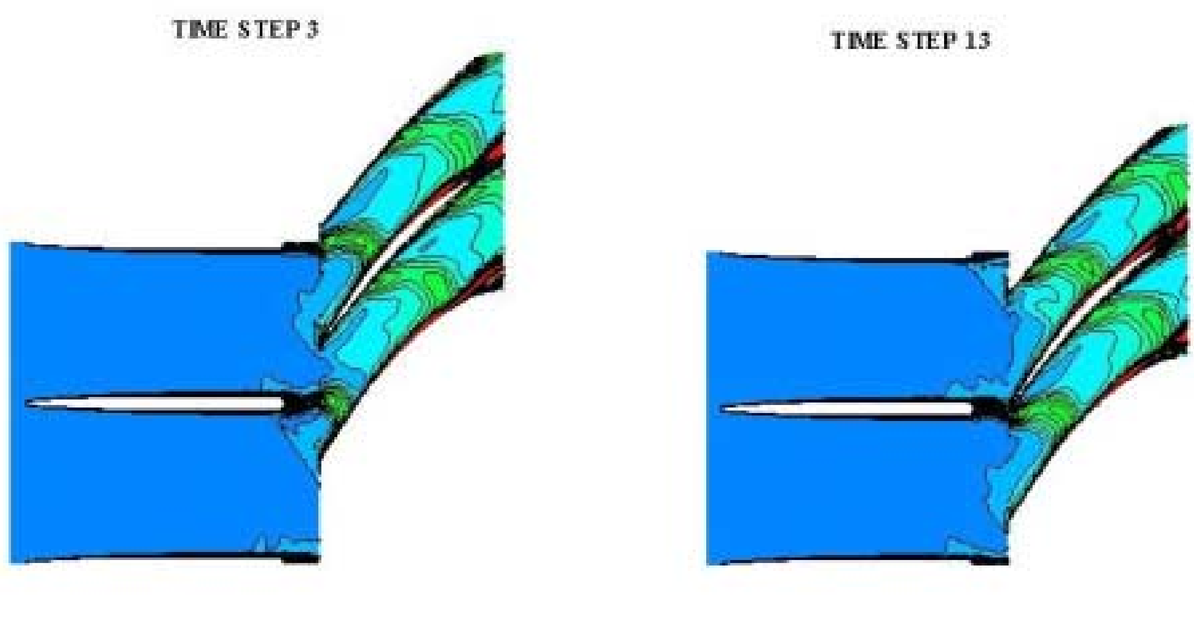
COMPRESSOR MODELING AND SIMULATION GOES UNSTEADY: The Propulsion Directorate's Compressor Research Group has successfully applied an unsteady three-dimensional Navier-Stokes CFD code to model a research compressor. This is the first in-house demonstration of such a code, which is a great enhancement to modeling and simulation capabilities. MSU TURBO is a three-dimensional, viscous, time-accurate code that solves the Reynolds Averaged Navier-Stokes equations in Cartesian coordinates in the rotating frame of reference. Mississippi State University is developing the code with funding from NASA Glenn Research Center. To meet IHPTET (Integrated High Performance Turbine Engine Technology) and VAATE (Versatile Affordable Advanced Turbine Engines) goals, fans and compressors are being designed with increased stage loading and closer axial blade-row spacing. Consequently, unsteady blade-row interactions are having a significant impact on performance and High Cycle Fatigue (HCF). Accurate analysis of these complex flowfields is imperative to understanding the flow physics which affect HCF and stage performance. Both industry and NASA are using MSU TURBO to model turbines and compressors. The code is being used to model the Stage Matching Investigation (SMI) rig that was tested in PR's Compressor Aero Research Lab (CARL). Experimental data from the SMI rig test has shown that axial blade-row spacing affects the rotor efficiency and pressure ratio. MSU TURBO is being used to model the unsteady interaction between the stator and transonic rotor in an effort to understand the flow physics driving the change in compressor performance with axial blade-row spacing. The code, which was run on a Cray supercomputer at the Naval Oceanographic Office Major Shared Resource Center (NAVO MSRC), took approximately 225 hours of CPU time to reach a converged solution. A parallel version of the code is under development that will allow MSU TURBO to be run locally at PR's new Turbomachinery Computational Analysis Facility (TurboCAF). (S. Gorrell, AFRL/PRTF, (937) 255-4738)



Contours of loss for the SMI rig at two different times as the rotor rotates past the stator

SCRAMJET TEST FEATURED ON *AVIATION WEEK* COVER: The Hypersonic Technology (HyTech) Program's Performance Test Engine (PTE) was featured on the cover of the 26 March 2001 issue of *Aviation Week & Space Technology*. The cover story, written by Stanley W. Kandebo, is titled "Landmark Tests Boost Scramjet's Future." This article describes the recent successes achieved in freejet testing of a heavyweight hydrocarbon-fueled scramjet engine (i.e., the PTE). This issue also features a second article by Mr. Kandebo on the HyTech Program titled "Testing Key to Scramjet Success." This article describes the building block development approach taken in the HyTech Program, which led to the successful development and test of the PTE. This approach will lead to the ground test of a flight-type scramjet engine in 15 months. Flight testing of the scramjet could occur as early as the end of FY04. The HyTech Program is run by the Propulsion Directorate's Aerospace Propulsion Office (AFRL/PRA), and Pratt & Whitney is the primary contractor developing the scramjet engine. (R. Mercier, AFRL/PRA, (937) 255-5221)

The PTE installed in Leg VI at GASL

Want more information?

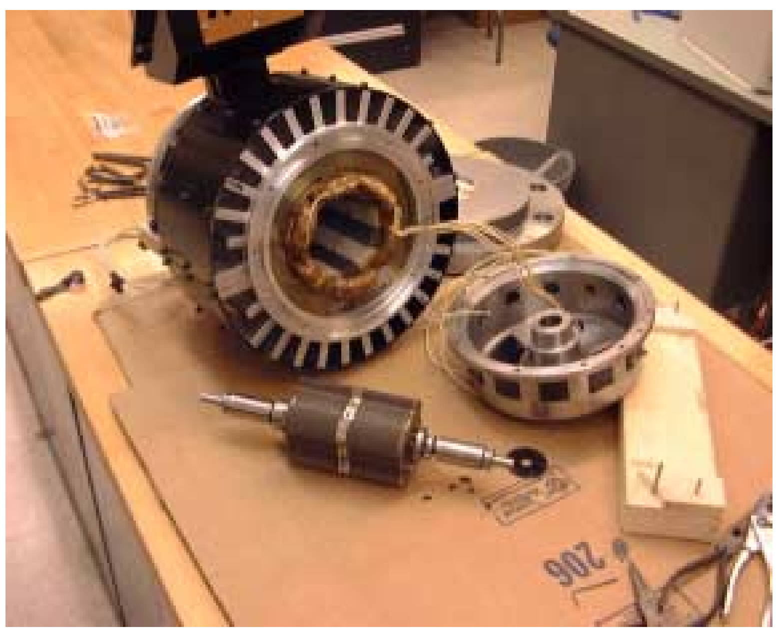
- The *Aviation Week* cover article, "Landmark Tests Boost Scramjet's Future," is available on-line by clicking here.

LAB AIRMAN PICKED FOR TOP HONORS: Senior Airman Jason W. Brock was recently named the Air Force Research Laboratory's Airman of the Year for 2000. He received this honor on 28 February 2001 at a Wright-Patterson AFB military awards banquet hosted by AFRL Commander, Brigadier General Paul D. Nielsen. AFRL's selection of SrA Brock was based on his leadership and outstanding job performance, and he was cited as an example of "The best people providing the best technologies . . ." He serves as a research machinist and welder at PR's "Rocket Site" at Edwards AFB where he has had numerous opportunities to demonstrate his skills and learn new ones. His efforts include manufacturing components for an international hybrid rocket motor program, machining Carbon-Carbon materials for NASA's Hyper-X Program, welding for one of the lab's largest Electric Propulsion space chambers, and supporting altitude testing for prototype Pulsed Detonation Rocket engines. He graduated last year from Airman Leadership School winning both Distinguished Graduate and Leadership Awards. He also recently completed his Community College of the Air Force Associates Degree in Metals Technology. Furthermore, he was one of only four Airmen worldwide to be featured in a recent video about how the Air Force changed their lives. In addition to being selected as Airman of the Quarter for Edwards AFB, he was selected as the AFRL's Propulsion Directorate's Airman of

SrA Jason W. Brock

the Year for 2000, which enabled him to compete for the AFRL honors. He will now be entered into the Air Force Materiel Command's "Airman Of the Year" competition to be held later this year. (R. Adams, AFRL/PROI, (661) 275-5465)

NEW ELECTROMACHINE TESTBED FOR HIGH-SPEED RESEARCH: The Propulsion Directorate's Power Generation Branch (AFRL/PRPG) recently took delivery of an electromachine that will serve as an experimental testbed for various machine mechanical and controls technologies. This is a switched-reluctance (SR) type machine, configured for 3-phase operation with a 6-pole stator and 4-pole rotor. Power rating is estimated at 100 kW when operating at 60 krpm speed, although the present rotor system is limited to 40-45 krpm operation. Both the rotor and the stator have been configured such that the rotor impels pole gap air into the stator midsection as a cooling air flow. The optimization of cooling methods and thermal management for high-speed, high-power machines for the Electromechanical In-house Program is one research topic to be addressed using this testbed. Other planned research topics using this testbed include: SR machine rotor angular position recognition through control algorithms instead of physical sensors (i.e., "sensorless" control); SR machine "self-excitation" by means of special stator windings and permanent magnet inserts; high-speed laminated rotor dynamics behavior; and verification of the mechanical performance of future soft magnetic alloys enhanced for high strength and high-temperature operation. The testbed allows verification of the technologies as integrated together to improve the machine design knowledge base for high-speed, high-power operation at elevated operating temperatures. These operating conditions are anticipated for some generators of future air platforms that may serve as power sources providing higher power demand for flight controls, avionics, or onboard directed-energy devices. (E. Durkin, AFRL/PRPG, (937) 255-6241)

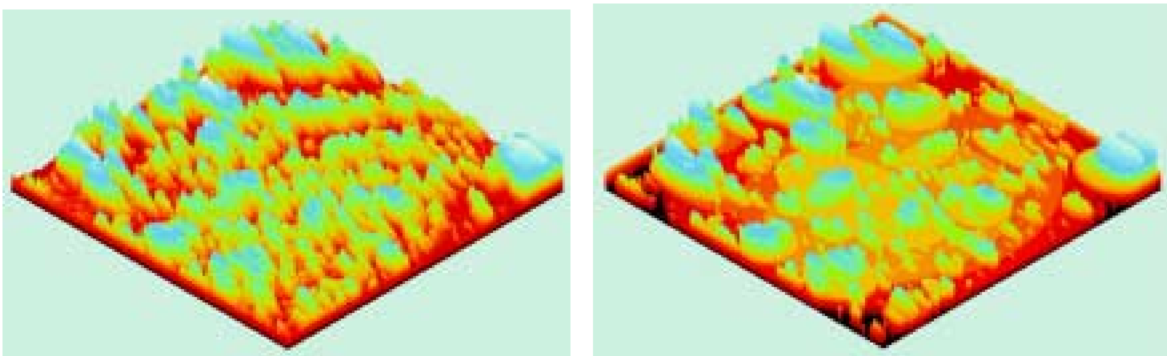


Experimental switched-reluctance machine (disassembled)

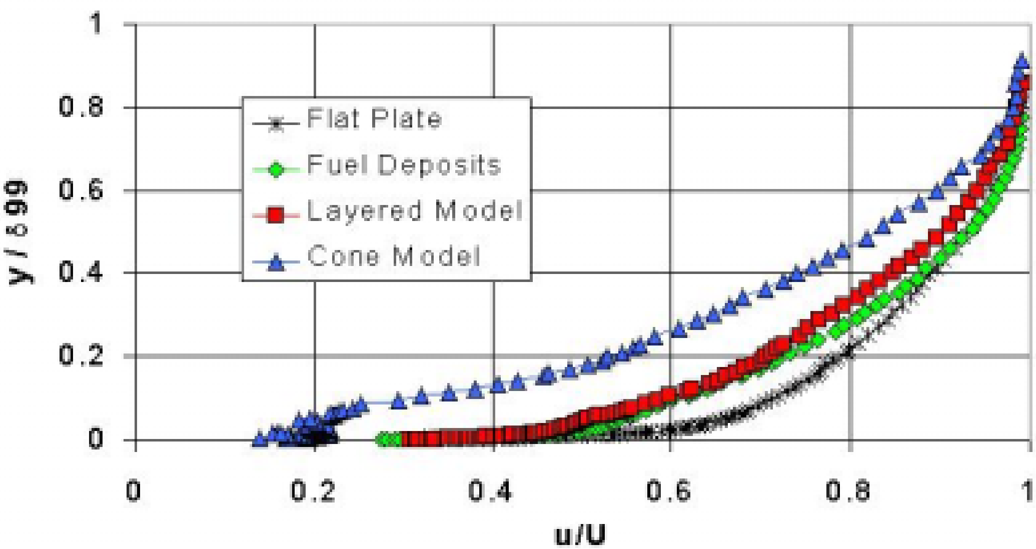
AWARD HONORS SCHARIO'S EFFORTS IN TECH TRANSFER: Ms. Kristen Schario of the Propulsion Directorate's Integration & Operations Division (AFRL/PRO) was chosen by the Federal Laboratory Consortium (FLC) for Technology Transfer as the 2001 recipient of the FLC's Representative of the Year Award. This award, which is one of FLC's highest honors, recognizes the FLC Representative who has made the most significant contributions to the FLC Program in the past year. Ms. Schario's efforts have demonstrated a great commitment to the promotion of technology transfer. She has been instrumental in identifying potential government partners for research efforts and in sharing successful technology transfer assessment methods with other federal laboratories. She has also been a strong supporter of FLC's Awards for Excellence in Technology Transfer Program, and has consistently supported FLC publications such as the *FLC NewsLink*. Ms. Schario will be honored at an awards ceremony to be held on 1 May 2001 in Burlington, Vermont. (C. Reeves, AFRL/PROP, (937) 255-8209)


Ms. Kristen Schario

STUDYING REAL SURFACE HEAT TRANSFER EFFECTS: A DoE funded project to examine the effects of turbine aging on blade heat transfer is being conducted by a team of researchers from the Propulsion Directorate's Turbine Engine Division (AFRL/PRT), AFIT, and Mississippi State University (MSU). As turbines progress through their service life, blade surfaces change from having a smooth, almost mirror-like finish to having significant roughness. This can be due to a variety of factors including accumulation of soot and other fuel created or airborne deposits, surface pitting, spallation of thermal barrier coatings, thermal cracking, and erosion from cooling flows. Roughness enhances the heat transfer between the freestream flow and the turbine, resulting in higher heat loads and reduced life. Therefore, the ability to account for these aging effects is critical to designing blades that will meet life requirements. The goal of this project is twofold: (1) to characterize the effects of aging on real turbine blades, and (2) to develop a model which can accurately predict the heat transfer implications of increased roughness. To address the first goal, over 100 blades with various types and length of service were borrowed from four major turbine engine manufacturers. Precise three-dimensional surface measurements were taken at critical points on each blade and the results were compiled and published. Once the types and magnitudes of surface roughness on real blades had been determined, selected surfaces were chosen for detailed study and model development. Computational model development is being performed at MSU, while experimental characterization of the real surface heat transfer effects is being performed on 50X scale models of the actual measured surfaces and selected modeled (simplified) surfaces in PRT wind tunnels. The experimental measurements will be used to refine and validate the computational models. Initial results show good agreement between experimental data from the actual surfaces, experimental data from the modeled surfaces, and computational data from the modeled surfaces. (R. Sondergaard, AFRL/PRTT, (937) 255-6768)

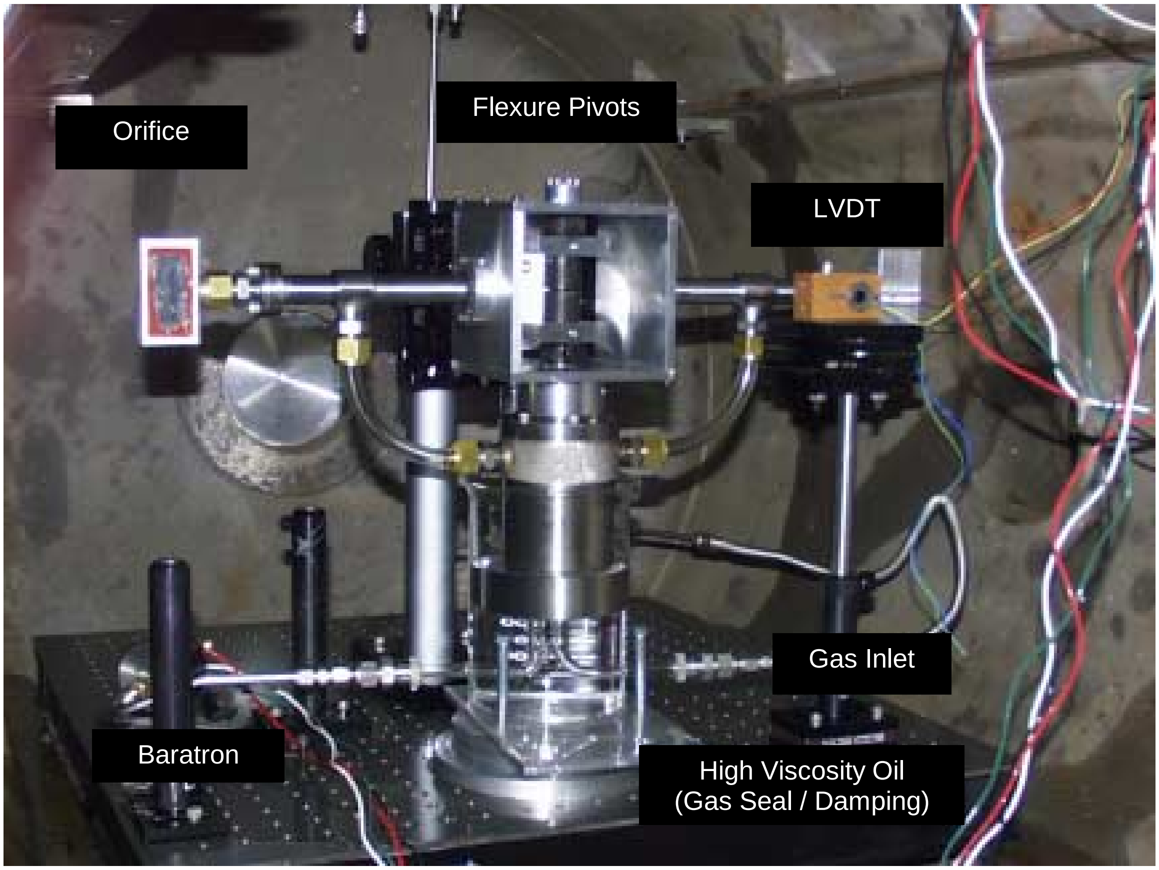


Roughness due to fuel deposits - actual surface (left) and modeled surface (right)



Results showing that modeled surface boundary layers are a good match to experimentally measured boundary layers

THRUST STAND SETS LOW THRUST MEASUREMENT RECORDS: A unique thrust stand capable of measuring the minuscule forces generated by micropropulsion systems continues to set new records for accurate, low thrust measurements. This thrust stand, developed by the Propulsion Directorate's Aerophysics Branch (AFRL/PRSA) and the University of Southern California, was built to measure the minute thrust of the Free Molecule Micro-Resistojet (FMMR). In recent shakedown tests, the stand measured a thrust of 1.2 micro-Newtons with an accuracy of ±10%, and thrust levels as low as 0.2 micro-Newtons have been measured with an accuracy of ±40%. The accuracy at the low end of the thrust scale will be improved in the immediate future by addressing electronic noise, facility vibration, and sensor drift problems. These measurements with their associated accuracies are better than any found in the literature to date. This thrust stand was developed in support of the FMMR flight experiment which is to be flown on a microsatellite being built by Arizona State University (ASU). One of the goals of the flight experiment is to demonstrate a safe and simple micropropulsion system. The FMMR addresses these micropropulsion needs, and it will be demonstrated in space. Satellite launch is scheduled for early 2003. (A. Ketsdever, AFRL/PRSA, (661) 275-5676)

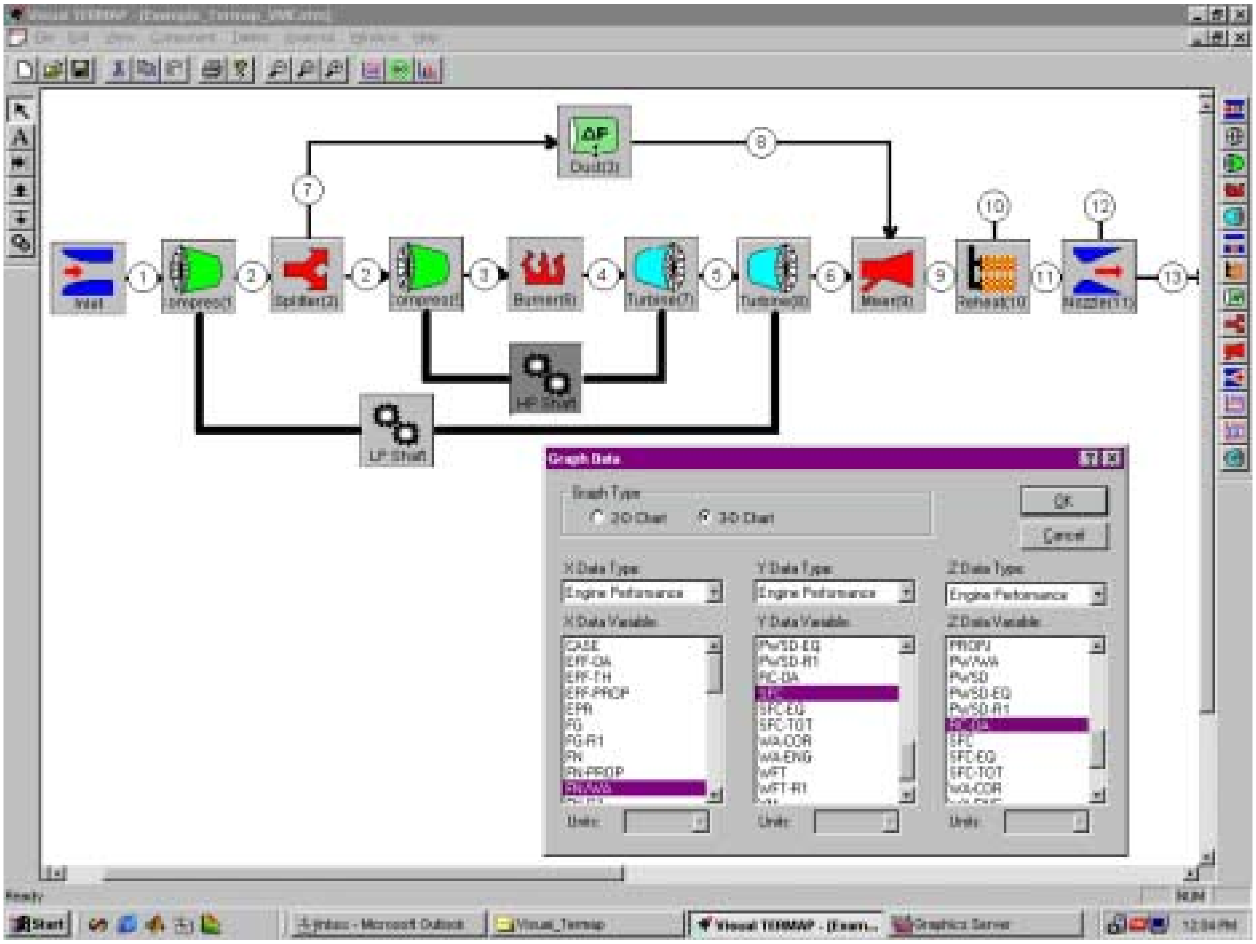


FMMR thrust stand

PR PARTICIPATION CONTRIBUTES TO SYMPOSIUM SUCCESS: The participation of Propulsion Directorate government and on-site contractor personnel was key to the success of the 26th Annual Dayton-Cincinnati Aerospace Science Symposium. This annual event, sponsored by the American Institute for Aeronautics and Astronautics (AIAA), was held in Dayton, Ohio, on 30 March 2001. The purpose of this symposium is to facilitate communication between members of the local technical community. The Executive Co-chairs for this year's symposium were Dr. James R. Gord of the Propulsion Directorate and Mr. Gary Dale of the Air Vehicles Directorate. PR government or contractor personnel chaired 13 of the 41 technical sessions held at the symposium. Furthermore, this year's symposium included more than 150 technical papers, almost a quarter of which featured at least partial authorship by PR personnel. By all accounts, this was yet another in a long line of successful symposia. (J. Gord, AFRL/PRTS, (937) 255-7431)

PULSED PLASMA THRUSTER SETS NEW DURATION RECORD: Researchers in the Propulsion Directorate's Spacecraft Branch (AFRL/PRSS) recently completed a record setting Micro Pulsed Plasma Thruster (MicroPPT) test. In this test, a MicroPPT of proprietary design was fired continuously for 240 hours, which is the longest continuous firing of a MicroPPT performed to date. Furthermore, this test was voluntarily terminated suggesting that even longer duration operation is possible. The duration demonstrated in this test is in excess of the lifetime needed for the TechSat21 flight. This recent test was performed at a power of 4 Watts using a ¼” diameter propellant. Continued measurements using this design will characterize the propellant consumption rate over long time periods to determine whether the ¼” diameter propellant is the sole provider of accelerated material after significant propellant recession has occurred. Pulsed Plasma Thruster (PPT) systems provide thrust by electromagnetic acceleration of propellants using a discharge of energy. This technology is being developed for space applications, and engineers are continually exploring novel ways of making the technology more efficient, more reliable, and less expensive. (R. Spores, AFRL/PRSS, (661) 275-5528)

<u>PR TO PLAY KEY ROLE IN PROPULSION SOFTWARE DEVELOPMENT</u>: Organizations across Wright-Patterson AFB have been utilizing the gas turbine thermodynamic cycle analysis capabilities of TERMAP (Turbine Engine Reverse Modeling Aid Program) for nearly 20 years. This extremely robust package, originally developed by Detroit Diesel Allison (now a subsidiary of Rolls Royce) for the organization that is now the National Air Intelligence Center (NAIC), has become the preferred/default package for general gas turbine performance modeling within the Air Force. It is also the standard package for predicting detailed performance characteristics of missile engines used by the Army Aviation and Missile Command (AMCOM). Due to its age, the mechanics of running TERMAP are outdated. SRS Technologies recently completed an Air Force funded SBIR Phase I Program to investigate the feasibility of applying a modern, graphical user interface (GUI) to TERMAP. The Phase I program was successful, and a Phase II program to incorporate all of TERMAP’s features into the user-friendly graphical environment is being funded by the Army. Representatives from AFRL and NAIC attended the February 2001 kickoff meeting for the Phase II program and were successful in modifying the program schedule and software requirements to better suit the needs of the Air Force. The Air Force will be directly involved in the development process, having access to all beta versions of the software and given a channel for providing direct feedback to SRS. Both AFRL and NAIC will receive the final deliverables of the Phase II effort, including the completed software, at zero cost to the Air Force. Of particular importance to the Propulsion Directorate is the implementation of a component object model (COM) interface to TERMAP. Just as the GUI will allow engineers to efficiently and easily use TERMAP, the COM interface will allow other software applications to run the program. This is a significant step in improving overall modeling and simulation (M&S) capability. With technology models that communicate information to one another autonomously, the benefits of modern multidisciplinary optimization techniques (i.e., genetic algorithms) may be realized in conceptual turbine engine design. (N. Kuprowicz, AFRL/PRTA, (937) 255-2121)



Modeling of a two-spool mixed-flow augmented turbofan in TERMAP

<u>PR PROVIDES MENTORS FOR EAGLE SCOUTS</u>: Six individuals from the Propulsion Directorate have generously given their time and energy to act as mentors for Eagle Scouts. Each of these six individuals was paired with a Dayton-area Eagle Scout with similar career aspirations. They were then able to provide these scouts with guidance on their chosen careers and relay to them the wisdom accumulated through years of personal experience. In addition, each mentor escorted his protégé to the Miami Valley Council, Boy Scouts of America, Eagle Scout Recognition Banquet held on 20 February 2001. The following individuals served as mentors: Capt Ralph Anthenien (AFRL/PRTS), Lt Chris Blackwell (AFRL/PRTF), Henry (Hank) Grinner III (AFRL/PROE), Jack Huey (AFRL/PROE), Urban Reinhart (AFRL/PRF), and Thomas Reitz (AFRL/PRPS). These six men are to be lauded for their selfless giving of time to this worthy program. (M. Novitski, AFRL/PRF, (937) 255-6130)

<u>HAGENMAIER NAMED FEBRUARY EMPLOYEE OF THE MONTH</u>: Dr. Mark A. Hagenmaier of the Propulsion Directorate's Aerospace Propulsion Office (AFRL/PRA) has been named PR's Employee of the Month for February 2001 in the Scientist and Engineer category. Dr. Hagenmaier has been a key contributor to the Hypersonic Technology (HyTech) Program. He is responsible for developing design strategies, performing computational studies, and analyzing computational fluid dynamics (CFD) and physical experimental results associated with the scramjet inlet. His insight into engine inlet flows has been invaluable in evolving the HyTech

engine design, and his guidance contributed substantially to the recent success of the HyTech freejet test. In addition to his work with HyTech, Dr. Hagenmaier also manages several Small Business Innovation Research (SBIR) and Dual-Use Application Program (DUAP) contracts. He continues to promote development of a sophisticated computational tool, originally developed under a SBIR contract, as a replacement for the CFD solvers currently used in scramjet development. He also serves as the systems administrator for the multi-processor Power Challenge computer and serves as PRA's Information Assurance Focal Point. He regularly publishes in the area of scramjet inlets and isolators. Dr. Hagenmaier is a Senior Member of the American Institute for Aeronautics and Astronautics (AIAA), and he serves as a technical reviewer for the AIAA *Journal of Propulsion and Power* and the independently published journal *Computers and Fluids*. (R. Mercier, AFRL/PRA, (937) 255-5221)

Dr. Mark Hagenmaier

PARTICIPATION IN JOINT WORKING GROUP FOR HIGH-VOLTAGE CRITERIA: In recent months, Dr. Dan Schweickart of the Propulsion Directorate has been participating in meetings of a collaborative NASA/Air Force Working Group on high voltage issues for power systems in a space-based environment. The working group includes representatives from NASA Marshall Space Flight Center (MSFC), NASA Glenn Research Center (GRC), and Auburn University. D. K. Hall, the working group chair, is currently serving as Technical Liaison between Space Operations at Johnson Space Center (JSC) and the MSFC Engineering Directorate. As such, one task is to support the JSC Orbiter Upgrade Program. As an outgrowth of his presentations on high frequency breakdown at the 1998 High Voltage Workshop, D. K. Hall specifically requested Dr. Schweickart's participation on the Working Group. This group was convened to revise and republish NASA document MFSC-531 entitled "High Voltage Design Criteria" originally written over 20 years ago by William G. Dunbar. It is essentially a compilation and updating of previous guides and published literature written under either Air Force or NASA sponsorship. The motivation for this was to support the recent design phase of the Orbiter Upgrade Program, which is planning to incorporate a battery-powered electric auxiliary power unit (EAPU) to replace the hydraulic powered APU in the current vehicle. Together with this activity, the PRPG liaison was asked to provide preliminary HF breakdown data required for operation of the EAPU in specific gas environments; i.e., helium and carbon dioxide. Preliminary experiments were accomplished to establish system requirements for the design of the PWM driven motor in the Electric-Hydraulic Drive Unit (EHDU). A specific design criteria document was also written by the group to define the systems requirements and design specifications for the EHDU within the APU. A revised draft of the MFSC-531 update is anticipated in mid-2001, with initial publication through NASA. It is anticipated that this document will also be adopted and identified as an Air Force document as well. (D. Schweickart, AFRL/PRPG, (937) 255-9189)